



## Laser Metrology for an Optical-Path-Length Modulator

**Sensitivity is of the order of picometers.**

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Laser gauges have been developed to satisfy requirements specific to monitoring the amplitude of the motion of an optical-path-length modulator that is part of an astronomical interferometer. The modulator includes a corner-cube retroreflector driven by an electromagnetic actuator. During operation of the astronomical interferometer, the electromagnet is excited to produce linear reciprocating motion of the corner-cube retroreflector at an amplitude of 2 to 4 mm at a frequency of 250, 750, or 1,250 Hz. Attached to the corner-cube retroreflector is a small pick-off mirror. To suppress vibrations, a counterweight having a mass equal to that of the corner-cube retroreflector and pick-off mirror is mounted on another electromagnetic actuator that is excited in opposite phase. Each gauge is required to measure the amplitude of the motion of the pick-off mirror, assuming that the motions of the pick-off mirror and the corner-cube retroreflector are identical, so as to measure the amplitude of motion of the corner-cube retroreflector to within an error of the order of picometers at each excitation frequency.

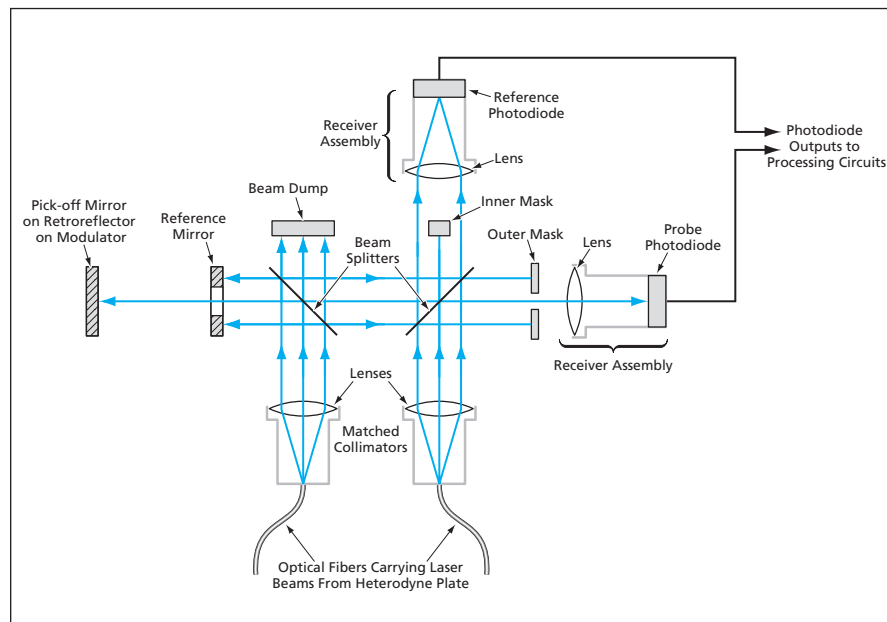
Each gauge is a polarization-insensitive heterodyne interferometer that includes matched collimators, beam separators, and photodiodes (see figure). The light needed for operation of the gauge comprises two pairs of laser beams, the beams in each pair being separated by a beat frequency of 80 kHz. The laser beams are generated by an apparatus, denoted the heterodyne plate, that includes stabilized helium-neon lasers, acousto-optical modulators, and associated optical and electronic subsystems. The laser beams are coupled from the heterodyne plate to the collimators via optical fibers.

The basic heterodyne-interferometer architecture is not new, but prior systems based on the architecture have not afforded accuracies as great as those of the present gauges. The novelty of the present gauges lies in numerous details of design, construction, and setup that, taken together, make it possible to obtain the required level of accuracy. Within the limited space available for this article, it is possible only to summarize a few major details:

- The gauge utilizes an inner beam pair in one of the interferometer arms (the probe arm) and an outer beam pair in the other interferometer arm (the reference arm). The beams are separated by (1) an inner mask and a mirror with a hole in the reference arm, and (2) an outer mask in the probe arm. Care is taken to provide a small radial separation between the beams to minimize leakage between them.
- In the design, construction, and setup of the collimators, great care is taken to eliminate scattered light, to adjust the collimator lenses to the collimating positions, and to match the collimator outputs. Although the wave fronts coming out of the collimators are not very flat, they are matched to within a fraction of the 633-nm laser wavelength. Once the collimators are adjusted to the required match, they are permanently glued in position.
- The photodetectors, and lenses that focus light on the photodetectors, are mounted in receiver assemblies, the optical configuration of which is the inverse of that of the collimators. The photodiodes are only 100 mm in diameter and are mounted at the precise focal points of the lenses. The precise placement and the smallness of the photodiodes helps to discriminate against leakage in the form of diffracted light, which travels at slight angles to the optical axes of the main masked beams.

Two of the gauges have been built and have been demonstrated to be capable of a sensitivity of  $\leq 3 \text{ pm/Hz}^{1/2}$  within 1-Hz-wide bands at each of 250, 750, and 1,250 Hz. When the gauges were tested while monitoring the same optical-path-length modulator, the root-mean-square systematic error per gauge was found to be about 25 pm. However, the systematic errors do not constitute a major drawback, inasmuch as they can be reduced by cyclic averaging and they occur at a frequency above 1,250 Hz.

*This work was done by Yekta Gursel of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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This **Laser Heterodyne Interferometer** utilizes an inner probe beam pair and an outer reference beam pair. High sensitivity and high accuracy are achieved through innovative design features and careful attention to detail in construction and alignment.